Pedobiologia, Bd. 11, S. 277—285 (1971)

Influence of Ant hills on the Meadow Soils

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(Accepted 15. 2. 1971)

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1. Introduction

Ants are insects appearing in dense population groups in both rich and poor soil. They are pioneers in settling in sandly, barren soil. The change they produce in the soil favours the development of vegetation. The influence of ants on the soil is connected with the building of hills. In meadow communities ants build hills on the ground in the form of mounds. The hills are composed of a number of passages, cells and galleries. Here the life of the community, composed of several thousand individuals, takes place. Here the food is brought, its remains and excrements buried.

Physical changes in the soil, consist of the mechanical mixing of its components in making the mound, carrying these components to the surface, which results in a more intensive aeration of the soil (Talbot 1953, Zigul'skaja 1966). The ants way of life within the hills also produces chemical changes in the soil and causes a rise in pH within the hills (Dlussky 1967, after Grinfield and Krupiennikov), as well as a rise in the index of the general biological activity as determined from the evolution of carbon-dioxide and the amount of nitrogen (Dmitrienko 1966).

The results previously presented by Pętal, Jakubczyk, Wójcik 1967, and Czerwiński, Jakubczyk, Pętal 1969 show that chemical changes within ant hills also include an increased content of available K_2O and P_2O_5 as well as organic carbon and nitrogen. The processes are accompanied by changes in the intensity of microflora development; that is, in number of aerobic, heterotrophic bacteria, fungi and actinomycetales. These processes cause changes in the vegetation on former ant hill sites.

2. Investigation area

In 1967 and 1968 investigations were conducted in four grassland environments in the vicinity of Warsaw. There is an extreme difference among them with respect to the physical and chemical properties of the soil and the plants growing on them:

(1) Strzeleckie Meadows, situated in the north-eastern part of the Kampinos Forest, are the natural mid-forest meadows, not cultivated for nearly ten years. The association Stellario-Deschampsietum Freitag 1957, belonging to periodically moist meadows (Molinietalia order), frequently appears here (Traczyk 1966).

The soil of Strzeleckie Meadows was formed of loose alluvial sand (Table 1) of the old accumulation terrace of the Vistula river during conditions of great periodical moisture. Groundwater in spring appears at the depth of 15 cm below the surface, gradually dropping to 70 cm in summer. The main soil-forming process in Strzeleckie Meadows is the biological accumulation of a turned -to-peat humus in the top layers resulting in the formation of black muck-like soil.

(2) Meadows near Kazuń (district Nowy Dwór Mazowiecki) are fresh meadows with a vegetation belonging to the order Arrhenatheretalia. The investigated terrain forms part of a large complex of cultivated meadows.

Kazuńskie Meadows occur on fertile, very heavy silt-like alluvial soil (Table 1) of the youngest Vistula River accumulation terrace which has been separated from the river bed by a protective embankment. In the spring, the ground water level here appears at the depth of 40 cm, dropping to 100 cm in the summer months. The alluvial silty sediments contain large quantities of humus (Table 1) to a depth of 120 cm.

At present, browning processes are taking place in the Kazuń Meadows soil under the accumulation horizons, and in the zone below the ground water — reduction processes are occurring. Typologically, the Kazuń Meadows' soil is classed among the very heavy brown gleyed alluvial soils.

(3) Sobiekursk Meadows (Otwock district) are also fresh meadows of the Arrhenatheretalia order. They are situated on shallow alluvial silty loam which is a medium heavy soil. Because of its mechanical composition the soil belongs to very-fine sandy loam. In the subsoil coarse river sands occur. This soil is less moist, ground water only appears at the depth of 120 cm, and it is better aerated than the soil of Kazuń Meadows.

(4) The dunes, near Kazuń, are covered by scanty, pioneer vegetation at the stage of succession between the associations Corinephorethea and Sedoscleranthea.

The soil of the dunes belong to the inital stage of development with the morphological structure A_1/C. The humus horizon is 10 cm thick and light grey in colour, and gradually passes into loose yellow dune sand.

3. Investigation methods

The investigations included an evaluation of: (a) the ant species' composition and number of ant hills; (b) the physicochemical properties of the soil in: active ant hills (A), abandoned ones (B), and the top soil-layers uninhabitated by ants (K) and (c) the activity of soil microflora in samples taken accordingly.

(a) The evaluation of the population size in the ant hills on a series of statistical sample plots 25 m^2 in size (PĘTAL, in press). In these samples the number and dimension of ant nests, inhabited by particular species of ants, were considered. A series of such samples taken several times during the season permitted us to determine the intensiveness of the nest translocation activity.

(b) In ant hills and control samples, *p*H was determined by using the glass electrode, the content of available by K_2O and P_2O_5 the RIEHM's modification of EGNER's method, the content of exchangeable cations ($Ca^{\cdot\cdot}$, $Mg^{\cdot\cdot}$, $K^{\cdot}$ and $Na^{\cdot}$) in the 1 n NH_4Cl extract and the amount of organic carbon by the TIURIN's method. The organic matter was calculated from the amount of organic carbon applying the coefficient 1,724.

Table 1 Mechanical composition, *p*H and organic carbon content of the soils of investigated

Meadow community	Horizon	Depth in cm	*p*H in H_2O	*p*H in KCl	Carbon %	Organic matter %
Strzeleckie Meadows	A_1/M	8— 20	5.5	4.8	4.07	7.20
	A_1	20— 30	5.7	5.1	1.73	2.98
	C/G	30— 50	6.1	5.7	0.05	0.08
	C/G	70— 90	6.2	5.6	0.03	0.05
Kazuńskie Meadows	A_1	0— 10	6.0	5.4	2.57	4.43
	A_1	10— 20	6.4	5.7	1.91	3.29
	(B)/G	30— 40	6.4	5.5	1.10	1.90
	Go_r	50— 60	6.7	5.5	0.75	1.29
	G_r	70—100	6.7	5.5	1.17	2.02
	G_r	100—120	6.9	5.6	0.70	1.21
Meadows of Sobiekursk	A_1	10— 20	7.0	6.6	2.73	4.71
	G	60— 70	7.0	6.4	0.09	0.15
	G	110—120	6.8	6.2	0.06	0.10

(c) Simultaneously, the number of ammonifying bacteria per 1 cm³ of soil was determined by plating on a meat-peptone agar medium; the number of fungi were determined on the Martin's medium with an addition of antibiotics and Bengal-rose and the number of Actinomycetales were determined on a starch-ammonia medium.

In all environments the hills of the dominant species *Myrmica* sp. in Strzeleckie, Kazuń and Sobiekursk Meadows, and *Formica cinerea* L. on the sandy dune near Kazuń were subjected to intensive soil and microbiological investigations.

In the Strzeleckie Meadows, the influence of the species *Lasius flavus* F. and *Lasius niger* L. on the changes in their soil habitat has also been the subject of investigations.

4. Results

4.1 Ant populations in the environments

In the investigated meadows, the specific composition of the ant population is similar. These environments, however, differ in the number of ant hills and the contribution of the particular species (Table 2). Differences in the dimensions of ant hills were also noted; that is the mounds were higher on the more moist meadows.

Ants of the *Myrmica* species, *Lasius flavus* and *L. niger* are dominant in Strzeleckie Meadows, near Kazuń and in Sobiekursk. The sand dunes near Kazuń are mainly occupied by *Formica cinerea* together with a small number of *Lasius niger*. The latter species build their hills under the ground so that only the holes are visible on the surface. There are, on the average 6—14 holes to 1 m², from which about 30 ants emerge in a 24-hour period.

There are three trophic groups among the investigated ants which are connected with the manner in which they affect the soil.

(1) The *Myrmica* species are mainly predators bringing numerous small invertebrates to the nest, especially in summer, and burying their remains there.

(2) *Lasius niger* is a semi-predatory species, partly feeding on grass seeds and also breeding aphids within the nest.

(3) *Lasius flavus* seldom leaves the nest, does not forage and feeds mainly on the honey-dew of root aphids bred within the nest. The nests of this species remain in the same place for years on end, and are extended upwards above the ground.

In all the environments investigated the ant hills are characterized by their assembly-like plan. In 25 m² sample plots the index of dispersion — V reaches up to 2.28 which limits the effect of ant nests on the environment to definite patches.

meadow communities

Per cent content of mechanical fraction of diameter in mm						
> than 1	1—0.1	0.1—0.05	0.05—0.02	0.02—0.006	0.006—0.002	< than 0.002
0.1	80	4	5	4	3	4
0.2	81	4	3	6	2	4
0.2	90	2	1	3	1	3
0.8	90	6	1	0	2	1
0.3	7	8	27	20	24	14
0.0	7	7	25	22	15	24
0.0	9	4	22	27	15	23
0.0	9	7	27	23	16	18
0.0	20	7	12	18	16	27
0.5	31	11	18	12	10	18
0.0	35	14	22	14	11	4
0.1	80	6	6	3	3	2
0.1	85	4	2	1	3	5

Table 2 Number and size of anthills

Ant species	Strzeleckie Meadows					Kazuńskie Meadows	
	Number of anthills on 100 m^2	Size of anthills in cm			Area occupied by anthills per 100 m^2	Number of anthills on 100 m^2	Size of
		Diameter	Height	Depth			Diameter
Myrmica rubra L.	5	12.3	7.4	20	593.8	3.2	14.0
Myrmica ruginodis NYL.	1	13.2	7.3	10	43.6	2.4	14.0
Myrmica scabrinodis NYL.	10	12.3	3.0	10	1187.5	0	—
Lasius flavus F.	3	29.6	11.4	20	2063.7	4.0	10.0
Lasius niger L.	1	19.0	6.0	20	283.4	3.2	12.0
Total	**20**				**4172.0**	**12.8**	
Area occupied by anthills abandoned during the season					3293.7		

Table 3 Chemical properties of the control soil (K) and of the anthills occupied (A) and aban-

Meadow community	The species of ants	Sample	Depth in cm	pH		Exchan-
				in H_2O	in KCl	$Ca^{\cdot\cdot}$
Strzeleckie Meadows (1968)	*Myrmica* sp.	K	0–10	5.5	5.2	13.27
		K	10–20	5.7	5.3	8.88
		A	—	5.7	5.4	16.67
		A	—	5.8	5.4	16.67
		B	—	6.2	5.8	26.54
		B	—	6.3	5.8	24.55
	Lasius flavus	K	0–10	6.35	5.9	12.17
		A	—	6.60	6.3	17.66
		A	—	7.15	6.9	17.96
	Lasius niger	K	0–10	7.0	6.7	17.96
		A	—	7.4	7.1	18.36
		K	0–10	7.2	6.9	17.96
		A	—	7.5	7.3	17.26
Kazuńskie Meadows (1968)	*Myrmica* ssp.	K	0–10	6.3	5.8	28.04
		A	—	6.25	5.9	24.95
		A	—	5.8	5.2	23.65
		A	—	6.2	5.8	25.85
Sobiekurskie Meadows (1967)	*Myrmica* ssp.	K	0–10	6.7	6.1	—
		K	—	7.0	6.5	—
		A	—	7.0	6.2	—
		A	—	6.6	6.1	—
		B	—	6.8	6.2	—
The sand dune near Kazuń (1967)	*Formica cunicularia* L.	K	0–10	4.9	4.2	—
		A	0–10	5.1	4.4	—

			Sobiekurskie Meadows				
anthills in cm				Size of anthills in cm			
Height	Depth	Area occupied by anthills per 100 m²	Number of anthills on 100 m²	Diameter	Height	Depth	Area occupied by anthills per 100 ²
6.0	15	492.5	6.2	10.0	4.0	10.0	486.7
6.0	15	369.4	3.8	10.0	4.0	10.0	298.3
—	—	—	0	—	—	—	—
8.2	15	314.0	0.2	8.0	3.6	10.0	10.0
7.6	15	361.6	0.08	12.0	8.0	10.0	9.0
		1537.5	**10.28**				**804.0**
		861.9					785.0

doned (B) by the ants in four meadows communities

geable cations in m-eq/100 g of soil				Content in mg/100 g of soil determined by Egner's method		Carbon	Organic matter
$Mg^{\cdot\cdot}$	$K^{\cdot}$	$Na^{\cdot}$	Sum $S_1 = Ca^{\cdot\cdot} + Mg^{\cdot\cdot} + K^{\cdot} + Na^{\cdot}$	K_2O	P_2O_5	%	%
0.23	0.13	0.23	13.86	4.3	0.9	3.44	5.93
0.07	0.04	0.13	9.12	1.3	0.7	1.07	1.83
1.41	0.28	0.29	18.65	16.0	3.3	6.16	10.62
1.13	0.29	0.24	18.33	16.8	3.8	5.81	10.02
2.36	0.47	0.33	29.70	26.9	5.2	7.70	13.27
0.95	0.25	0.27	26.02	11.0	2.8	5.57	9.60
0.38	0.07	0.20	12.82	1.3	1.0	3.78	6.52
1.41	0.18	0.30	19.55	5.0	4.0	4.27	7.36
1.27	0.18	0.49	19.90	5.6	3.0	5.69	9.81
1.27	0.07	0.21	19.51	+	1.0	3.45	5.95
1.58	0.08	0.30	20.32	1.1	2.3	2.72	4.69
1.08	0.08	0.23	19.35	0.8	0.8	2.13	3.67
1.52	0.15	0.31	19.21	2.0	2.2	1.90	3.27
4.93	0.33	0.33	33.63	9.1	3.6	3.79	6.53
4.37	0.29	0.30	29.91	12.0	5.0	5.67	9.77
5.76	0.42	0.32	30.15	15.6	5.0	4.86	8.38
6.08	0.38	0.30	32.61	9.2	5.3	4.62	7.98
—	—	—	—	7.4	5.6	7.27	12.50
—	—	—	—	6.0	4.4	6.65	11.44
—	—	—	—	5.8	11.6	7.50	12.90
—	—	—	—	10.6	5.1	6.82	11.73
—	—	—	—	12.4	8.1	12.62	21.70
—	—	—	—	0.0	1.3	0.05	0.09
—	—	—	—	0.0	1.8	0.18	0.31

Species of the *Myrmica* genus vacate the hills once, twice or even more times during the season and build new ones. This greatly extends the area influenced by these ants (Table 2).

4.2. The influence of ants on the chemical properties of the soil

The greatest changes in the chemical composition of soil are caused by ants of the *Myrmica* genus in black muck-like soil of the Strzeleckie Meadows (Table 3). In comparison with the control soil (K) *p*H rises by 0.5—0.7 in inhabited hills; the amount of potassium and available phosphorus also rises a great deal and there is as similar rise in the content of organic matter and total nitrogen. In abandoned ant hills the amount of the above components remains at the same level. However, with the passage of time and the dwindling of the mound their amount decreases returning to the initial level. In extremely dry oligotrophic soil (sand dune near Kazuń) and in very fertile soil formed from alluvial sediments (meadows in Kazuń and Sobiekursk), the influence of ants on changes in chemical properties is much smaller (Table 3). In soil, formed from dune sand, only a very slight rise in *p*H and an insignificant rise in the phosphorus content were noted in ant hills; while the content of organic matter present in the control samples in only negligible amounts rises in the ant hills by approximately 300%. In ant hills situated in alluvial soil a slightly higher content of available potassium, phosphorus and organic matter have been observed in comparison with the control soil.

The regularity of these changes has been confirmed for the *Myrmica* species during the two years of investigations in Strzeleckie Meadows (Czerwiński, Jakubczyk, Pętal 1969) and in Kazuń.

In investigations on the effect of various kinds of ants in Strzeleckie Meadows it has been observed that the greatest changes in soil environment are caused by *Myrmica* sp. and *Lasius flavus*. In ant hills of this species there is an increase in *p*H as well as in the amount of organic matter and available potassium and phosphorus (Table 3). There is also an increase in the amount of exchangeable basic cations: Ca··, Mg··, K· and Na·. Their total amount (S_1) in a layer of soil 0—10 cm deep, amounts to 12.82—13.86 m-val per 100 g.

In the ant hills of *Lasius niger* the *p*H, as compared with the control soil, is slightly increased, an increase in the amount of potassium and available phosphorus is also noted and there are no great differences (except Mg··) in the content of basic cations; on the other hand the content of organic matter decreases. This might be connected with the intensive development of bacteria and fungi in ant hills belonging to this species (Table 4).

The microorganisms decomposing the humus which is the principal component of the adsorption complex in the investigated soil, diminish the exchange capacity. Basic cations freed in this way are easily washed out of the hills into the soil during the rainy periods. Moreover it would seem that the bacteria themselves may biologically absorb large amounts of basic cations.

4.3. Changes in the development of soil microorganisms under the influence of ant-activity

The presented results (Table 4) show that in all grassland communities in ant hills inhabited by the dominant species, the development of bacteria and fungi greatly increases whereas the population size of Actinomycetales decreases. In abandoned ant hills, the microflora slowly returns to its usual level. The increase in the activity of bacteria and fungi in inhabited ant hills is a proof of intensification in the primary stages of decomposition of organic matter. On the other hand, the succession of Actinomycetales, taking place in abandoned ant hills is connected with further processes of mineralization and humification.

Table 4 Number of microorganisms in 1 cm³ of the control soil (K) and of the anthills occupied (A) and abandoned (B) by the ants of the Genus *Myrmica* in four meadow communities

Group of microorganism	Year	Strzeleckie Meadows			Kazuńskie Meadows			Sobiekurskie Meadows			The sand dune near Kazuń	
		K	A	B	K	A	B	K	A	B	K	A
Bacteria in millions	1967	28.0	117.7	29.3	54.5	72.2	56.3	58.7	24.7	44.5	8.5	11.6
	1968	55.8	686.5	188.8	140.8	628.7	328.7	—	—	—	—	—
Fungi in thousands	1967	430	830	197	190	346	154	534	190	786	818	976
	1968	400	1440	1280	650	2116	2574	—	—	—	—	—
Actinomycetales in thousands	1967	219.6	25.5	55.6	—	—	—	—	—	—	6	40
	1968	1189.0	181.0	938.0	2104	925.6	1528	—	—	—	—	—

Table 5 Number of microorganisms in 1 cm³ of control soil and of the anthills occupied by the 3 species of ants (samples taken in July 1968 in Strzeleckie Meadows)

Group of microorganisms	Control samples	Samples of anthills of		
		Myrmica ssp.	*Lasius niger*	*Lasius flavus*
Bacteria in millions	55.8	686.5	1547.1	141.6
Fungi in thousands	400	1456	4700	300
Actinomycetales in thousands	1189	181	208	1458

The most important changes in the bacterial and fungi activity were observed in muck-like soil in Strzeleckie Meadows, being less pronounced in the fertile alluvial soil in Kazuń and Sobiekursk and the least so in dune sand. In the latter environment an increase in the Actinomycetales population size in the ant hills was observed which is in contrast with other environments.

A comparison of the data of the control soil and inhabited and abandoned ant hills suggests certain differences in the reactions in certain groups of microorganisms. That is to say the population size of Actinomycetales in abandoned ant nests gradually rises to the level in the control soil. The bacteria population size suffers a violent drop, while the fungi are slower in reacting. Recently abandoned ant hills have larger numbers of bacteria than inhabited ones, returning to a normal level in the control soil only after a longer lapse of time. The regularity of these changes is confirmed by two-year investigations conducted in Kazuń and Strzeleckie Meadows (CZERWIŃSKI, JAKUBCZYK, PĘTAL 1969).

The changes in soil microflora activity in ant hills of particular species of ants is seen clearly in Table 5. The greatest changes are produced by the activities of *Lasius niger;* there is a 6-fold diminution in the development of Actinomycetales, a 10-fold intensification of the growth of fungi and 14-fold one of bacteria. Myrmica's influence is also quite strong; it causes about the same diminution in the development of Actinomycetales as the former species, a 3-fold increase in the development of fungi and an 8-fold one of bacteria. *Lasius flavus* produces a slight increase in the development of bacteria and maintains the more intensive development of Actinomycetales which testifies to the rapidly proceeding processes of complete mineralization.

The discussed differences are bounded with the way of life of particular ant species. Large amounts of organic remains accumulated in the predator's hills are favourable to the development of certain groups of microflora active in the primary stages of decomposition. On the other hand the intensive and stable processes of decomposition in *L. flavus* hills are connected with their food – aphid honey dew – which is easy and nearly fully mineralized. One cannot say however that this species, in contrast to the others which permanently inhabit~~e~~ the same hills, is better protected against the process of rotting by antibiotics or other bacteriostatic substance (GASPAR 1966).

5. Conclusions

Independent of the type of soil under the grassland communities, the ants occurring in them are very numerous, occupying from 0.15 to 0.75% of the total surface area. In inhabited as well as abandoned ant hills an enrichment of the soil in organic matter, total nitrogen, available potassium and phosphorus and exchangeable basic cations is noted. These changes are most pronounced in muck-like soil (Strzeleckie Meadows), less pronounced in fertile alluvial soil (Kazuń and Sobiekursk meadows). In oligotrophic soil (sand dune near Kazuń) the *p*H and phosphorus content undergo only a slight increase while the content of humus in comparison with control soil increases by about 300% within the ant hills, a fact not observed in more fertile environments.

The enrichment of the soil with easily assimilated food components and organic matter within the ant hills is accompanied by a marked intensification in the development of bacteria and fungi, and a simultaneous drop in the population size of Actinomycetales.

These changes are marked in muck-like soil, much less so in alluvial soil and are minimal in dune sand.

Among the species occurring in grassland environments, the most important changes in the physico-chemical properties of the soil are brought about by *Myrmica* sp. and *Lasius flavus*.

The greatest increase in microfloral activity was noted in *Lasius niger* ant hills and was less intensive in *Myrmica* sp. ant hills. This observation is connected with the different ways of life and the different manner of feeding of these two species.

Ant hills represent an additional source of humus and a source for nearly all mineral components necessary to plant life. This surely has an effect on the succession of vascular vegetation and biocenotic changes connected with it.

6. Summary

The results concern the effect of ant hills on various types of grassland and the part played by particular species of ants in the processes of transforming the soil. They include physico-chemical changes in the soil as well as changes in the soil microfloral activity.

The investigations have been conducted on clearly different grassland environments in the vicinity of Warsaw:

(1) On the natural mid-forest meadows with a muck-like soil.

(2) On two cultivated meadows situated on brown, gleyed alluvial soil.

(3) On the sandy dune with sparse, pioneer vegetation with the soil at the primary stage of development.

In all these environments ant hills occupy from 0.15 to 0.75% of the total surface. There occurs within the ant hills an enrichment of the soil in organic matter; in total nitrogen, available potassium, phosphorus and exchangeable basic cations. These changes are more distinct in muck-like soil, being weaker in fertile alluvial soil; whereas in oligotrophic dune sand the content of humus within the ant hills rises by about 300%.

The changes in the soil within the ant nest are accompanied by an intensive rise in the development of bacteria and fungi and a simultaneous drop in the population of Actinomycetales. This process is most marked in muck-like soil, less so in alluvial soil and minimal in dune sand.

The greatest changes in physico-chemical soil properties are brought by *Myrmica* sp. and *L. flavus*. The greatest rise in the activity of the microflora occurs in the ant hills of *L. niger*, a lesser increase in those of the *Myrmica* sp. and an insignificant change in those of *L. flavus*. These differences are connected with the way of life of the various ant species.

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